

Anatomy of a Repeater

FM hamming wouldn't be the same without these clever devices.

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“When you're driving through town, give me a call on the 94 machine.”

“I'll meet you at 3 o'clock on the 64 machine.”

On the *machine*? Talk about an understatement! A food processor is a machine. A lawn mower is a machine. But a *repeater*... is much more than a machine!

If repeaters didn't exist, 2 meters wouldn't be the most active Amateur Radio band in the United States. FM activity would be but a pale shadow of its present self without these wondrous devices. Do you own an FM rig of some kind? Without the help of your friendly neighborhood repeater, your range would be limited to a few square miles—not the hundreds or thousands of square miles you probably enjoy now.

In simplest terms, a repeater repeats. It's an electronic parrot. A repeater listens to a signal and repeats what it hears. Unlike a parrot, however, a repeater repeats the signal *while it's listening to it*. (Perhaps you could genetically engineer a parrot with two brains—one for listening and another for talking. I'll save that idea for *Scientific American*.)

This is a pretty neat trick for a “machine.” A repeater accomplishes this feat by listening on one frequency and transmitting on

another. It might use two antennas for this purpose or, more commonly today, it may transmit and receive simultaneously *on the same antenna*. Now *that's* a mind-bending concept!

Any Flavor You Choose

Repeaters can come in almost any flavor, from plain vanilla to the most complicated systems you can imagine (butter pecan with chocolate chunks?). A block diagram of a typical plain-vanilla repeater is shown in Figure 1. In most cases you have a transmitter, a receiver, a controller and an antenna.

As I've already mentioned, many repeaters use one antenna for transmitting and receiving. The magical device that makes this possible is known as a *duplexer*. Duplexers are very-narrow-bandwidth tunable filters that keep the transmit and receive signals separated at the point where they enter or exit the antenna system. You can imagine what would happen if, say, 200 W of RF was allowed to pass directly into the antenna jack of your receiver. Not only would your receiver become as deaf as a post, its lifespan would be measured in milliseconds.

Be careful not to confuse a duplexer with a *duplexer*, though. Duplexers (and *triplers*) are used to separate transmit and receive signals when they're at vastly different frequencies (usually different bands altogether). They're compact devices, intended for use with dual- and tri-band VHF/UHF transceivers. They allow you to operate these rigs on multiple bands with a single antenna.

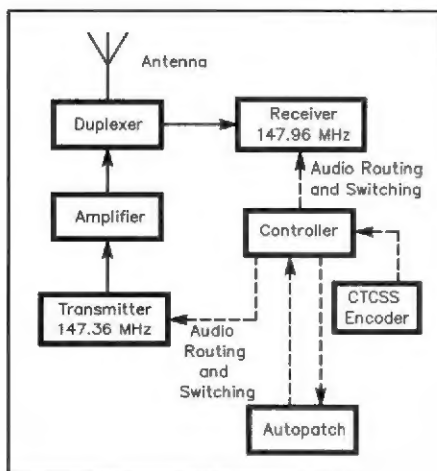
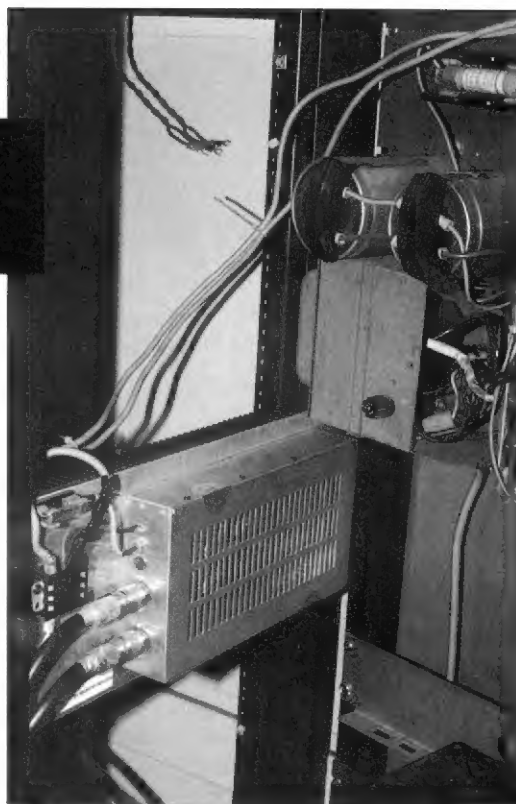


Figure 1—A block diagram of the W1KKF repeater. Notice how the controller is the nerve center of the system.



The W1KKF repeater transmitter generates about 30 W, which is boosted to 100 W, thanks to this amplifier.

When it comes to separating signals that are much closer in frequency, only a duplexer will do. Unfortunately, you'll often see duplexers referred to as duplexers in advertisements and catalogs. The difference is easy to spot, though. True duplexers cost \$800 or more, and you can't fit them under your dashboard!

A repeater antenna can be virtually any model that will get the job done. I've seen repeaters using everything from home brew J-poles to elaborate commercial antennas. For a repeater to function well, the antenna needs to be as high as possible. That's why hilltops and mountaintops are prized locations for repeaters. If an elevated chunk of terra firma isn't handy, you have to get the required height another way—usually with the help of a tall building or a tower.

The controller is the brain of the repeater system. It governs everything from the keying of the transmitter to the function of

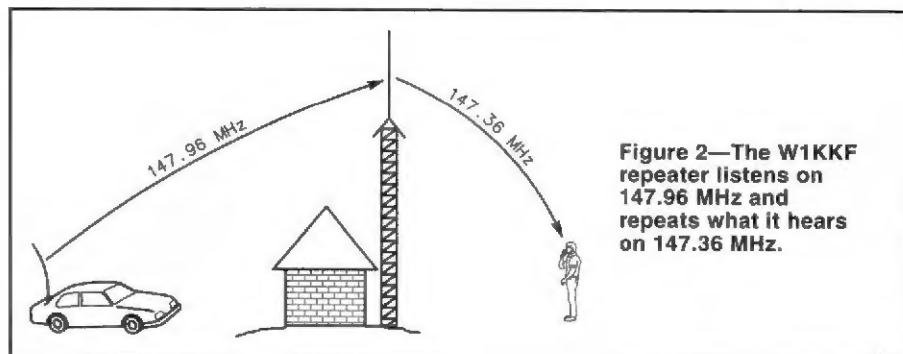


Figure 2—The W1KKF repeater listens on 147.96 MHz and repeats what it hears on 147.36 MHz.

the autopatch—and a *lot* of things in between! Like the repeater systems themselves, they can be relatively simple, home-built devices, or off-the-shelf units overflowing with every conceivable feature.

The WIKKF System

Describing a typical repeater system is easy—especially when it's located just a couple of miles from your home. The WIKKF repeater is the creation of the Wallingford (Connecticut) Repeater Association. It listens for signals on 147.96 MHz and repeats whatever it hears on 147.36 MHz (see Figure 2). Notice that the input and output frequencies are separated by 600 kHz. This is the standard separation for 2-meter repeaters, although you'll occasionally find other repeaters using different *splits*. On 50 MHz the standard is 500 kHz; 1.6 MHz is the common split on 222 MHz; and a 5-MHz separation is the plan at 440 MHz.

At the WIKKF repeater site you find a 90-foot tower supporting various antennas (see Figure 3). WIKKF's Cellwave collinear antenna gets the top spot. With this antenna and the 100-W transmitter output, you can use WIKKF from an H-T at a distance of about 10 miles in any direction. If you're running a 30-W mobile transceiver in your car, you can double that range.

Building a reliable repeater is an expensive proposition. That's why you often see repeaters financed by clubs or other groups. WIKKF is mostly a home brew system (see Figure 4), but its value is at least \$3000.

Autopatches

The WIKKF system includes an *autopatch*. Autopatches allow mobile and portable operators to place telephone calls through the repeater. Let's say I'm cruising around town and I see a car accident. By pressing three keys in sequence on my H-T's keypad, I can activate the WIKKF autopatch. I'll hear the dial tone when I release the push-to-talk (PTT) switch. Now I can transmit again, this time using the keypad to dial 911.

It's important to note that an autopatch is not the same as a cellular telephone. They both use RF, but the similarity ends there. Autopatches are comparable to old-fashioned "party lines." When you make an autopatch call, *everyone* gets an earful of your conversation. Cell phones are relatively private by comparison. Furthermore, autopatches are only *half-duplex* devices. This means that you and the person you've called must take turns talking. While you're babbling away, your buddy can't get a word in whatsoever. Cell phones, on the other hand, are *full duplex*; you can interrupt each other at will (or, with your spouse, both talk at the same time). Finally, autopatches are intended for short-term use. You make your call, speak your piece and get off. You can chat all day on a cell phone—if you can recover from the shock when you see your bill.

If the repeaters in your area have autopatches, you'll find that most use special touchtone codes for access. Because of the cost involved in maintaining autopatch-

equipped repeaters, these access codes are usually given only to dues-paying members of the group or club that sponsors the repeater.

Subaudible Tones

Subaudible means "below audible"; below the range of human hearing. Repeaters use these low-frequency audio tones for special purposes. Your ears can't hear them, but a repeater controller can detect their presence.

Subaudible tone generators and decoders are often lumped together under the term "continuous tone-coded squelch system," or CTCSS for short. If you're an FM repeater veteran, you know it better as *PL* or *Private Line*, the old Motorola trademark name. Modern FM transceivers include CTCSS generators (encoders), or at least provide them as options.

Most repeaters use subaudible tones as an effective way to deal with interference. When a repeater is using a CTCSS detection system, it will repeat only signals that carry the proper subaudible tone. An interfering signal, such as *intermod* caused by a nearby commercial transmitter, will be ignored.

The WIKKF repeater uses subaudible tones in an interesting way. The problem centers on a powerful repeater in the New York City area that shares the same repeater-pair of frequencies with WIKKF. Although the users of the New York repeater don't usually key up WIKKF, their repeater is powerful enough to be heard throughout a large part of WIKKF's coverage area when the band is open. As you can guess, anyone with a sufficiently sensitive receiver is driven insane by signals from two repeaters at once!

The solution? WIKKF transmits a 162.2-Hz subaudible tone whenever it repeats a signal. Hams who own radios with CTCSS squelches can set their rigs to respond only to signals that carry the 162.2-Hz tone. In other words, they won't hear a peep unless the signal is coming from the WIKKF repeater.

Courtesy Beeps

Courteous repeater operators leave periods of silence at the end of every transmission. This allows other hams to break into the conversation. Imagine being at the scene of an emergency and not being able to use the repeater because no one will pause long enough to let you make a call! And, sad to say, this has happened on repeaters more than once.

If every ham remembered his or her manners, we wouldn't need *courtesy beeps*, the little audio beep that occurs a couple of seconds after each transmission. Alas, this is not so. The only way to be sure that quick-trigger hams pause for breakers or for emergencies is by penalizing them if they don't. That's the purpose of the courtesy beep.

If users persist in starting to transmit before the courtesy beep sounds, they will run into another problem. Almost all repeat-

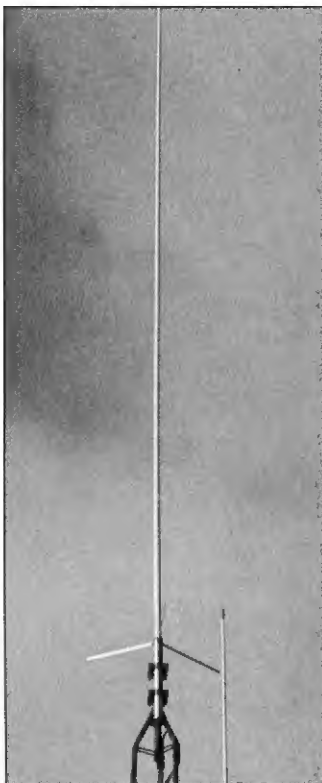


Figure 3—One of the secrets of WIKKF's success is a Cellwave PD-200 collinear antenna atop a 90-foot tower.



Figure 4—An inside view of the WIKKF repeater. The controller takes center stage, while the duplexer is visible at the bottom of the cabinet.

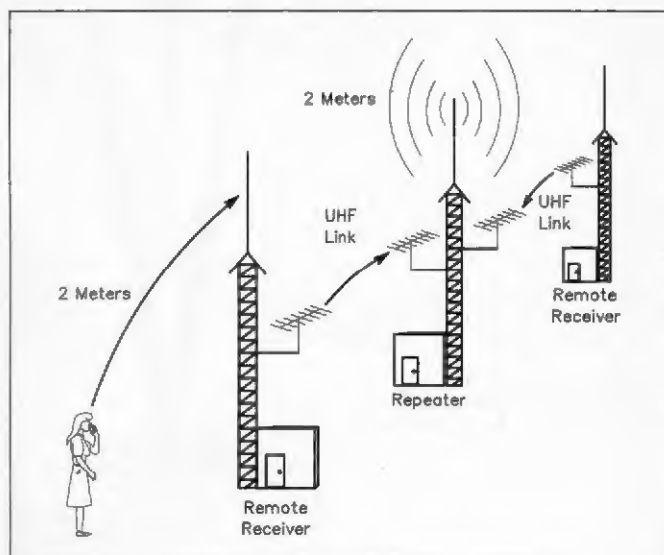


Figure 5—Many repeater systems use more than one receiver to provide reliable coverage.



ers today have *timers* built into their control circuitry, to keep long-winded operators from talking and talking.... If their transmission continues beyond the length of time set into the timer, the timer shuts the repeater transmitter down, so as to avoid dangerous situations such as putting the drivers of mobile stations to sleep from boredom.

When you release the PTT switch on your transceiver after a transmission, you usually hear a pause followed by a beep, and then you know the timer has reset to its full value. But if you start transmitting *before* you hear the beep, the repeater timer does not reset! It keeps counting down to zero, thinking there is still a long-winded user. When it reaches zero, it again shuts the repeater down. Oops! It looks like someone paid the price for not minding their manners.

Whether done by a single long-winded operator or by more than one operator in a trigger-happy shootout, this embarrassing situation is known as "timing out the repeater." It is good practice to forgive the new operator who does this before he learns to keep the time-out in mind, but if an experienced operator—one who should know better—times out the repeater with a long transmission, it is the typical practice to make gently sarcastic remarks to or about the offender to chide him or her into remembering to be more careful the next time!

Not all repeaters use courtesy beeps—the W1KKF system does not. But they are a very effective solution to ratchet-jaw repeater hogs. I like to think of them as the repeater equivalents of cattle prods applied to the buttocks.

Let's Get Complicated

So far we've been talking about simple repeater systems; one transmitter, one receiver and one antenna. Repeaters can become much more complicated, however.

Figure 5 illustrates a repeater system that has one transmitter, but many receivers. This is a great way to fill the "holes" in a

repeater's coverage. Each receiver sends whatever it hears back to the main site via a UHF or microwave link, or sometimes a telephone line. At the site there is a device that analyzes all the incoming signals and selects the strongest one to pass to the repeater transmitter.

You can usually tell when you're listening to a repeater system that's using remote receivers. If someone is carrying on a conversation while driving around town, they'll pass in and out of the coverage area of various receivers. As they do, you'll hear their signal become noisy, then switch to crystal clarity. (Cell phone users will recognize this!)

Repeater complexity doesn't end with multiple receivers on the same frequency. A repeater can have multiple receivers and transmitters on *other bands*. This allows *crossband linking*. For example, a 2-meter repeater may have a receiver and transmitter on the 222-MHz band so that Novices can join the 2-meter operators. The same repeater may have a transmitter and receiver on the 10-meter FM subband. When 10 meters opens up, everyone on the system—including the Novices on 222-MHz—can jump into the fray. (Before you ask—yes, this is all perfectly legal.)

The ultimate repeater coverage scheme is the *linked* system (see Figure 6). In this type of system, many repeaters are connected through UHF or microwave links to create a huge network that can spread over hundreds or thousands of miles. On a linked system, a ham in one city can talk to other hams in distant cities—with nothing more powerful than an H-T.

Linked repeater systems are popular in the Midwest and far West. The Evergreen

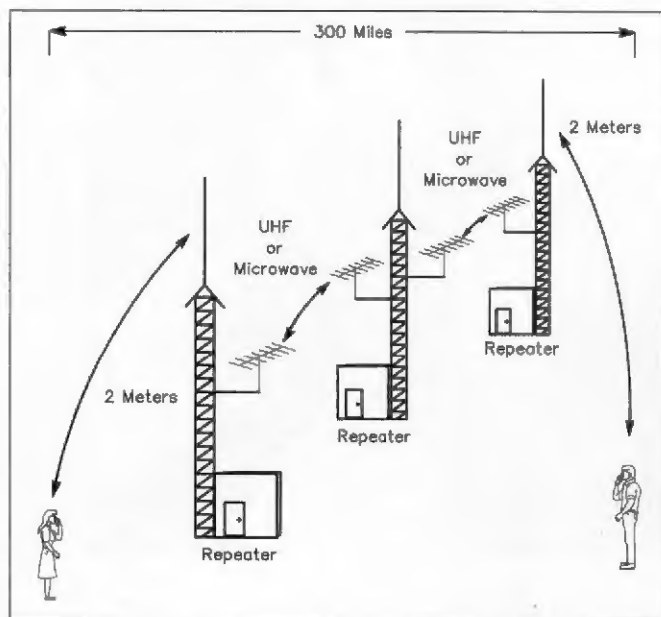


Figure 6—Linked repeater systems allow FM-active hams to cover huge areas with nothing more than an H-T.

Intertie, for example, covers much of California as well as Oregon, Washington and even parts of British Columbia. Hams who can tap the Intertie enjoy conversations up and down the West Coast! The downside of this, of course, is that only one conversation can take place at a time over this whole area. Such an intertie system requires even greater attention to short, courteous repeater usage.

Just the Beginning

Repeaters are even more wondrous than I've described. Some can give you signal reports, tell you if your keypad is working properly, or store voice-mail messages. Others have unusual (and sometimes entertaining!) voice identifiers. Do these sound like mere "machines" to you?

If you're among the small percentage of hams who haven't tried FM repeater operating, you're missing the fun. Get your hands on an FM transceiver (you can find inexpensive used rigs at just about any hamfest). Listen for several days and learn the repeater operating customs in your area. Then, when you're ready, pick up the microphone and jump right in. You're almost sure to get a friendly reception!

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